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(54) NUCLEAR REACTORS

(71) We, UNITED KINGDOM ATOMIC ENERGY AUTHORITY, London, a British Authority do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to nuclear reactors of the kind having a core composed of closely packed parallel fuel elements which are provided with bearing pads at selected levels whereby the elements are firmly positioned against one another to prevent them rattling. Such a nuclear reactor core is disclosed in British Patent No. 1,106,256 and the fuel elements in that reactor core are arranged in groups in each of which each element is supported in such a manner as to tend to tilt the element towards the centre of the respective group whereby the elements of each group are urged laterally into firm engagement either with one another or with a structural member around which the group may be arranged. Thus the elements of each group are jammed together, and, where desirable, about a central post on which the surrounding elements lean.

According to the present invention, in a nuclear reactor core comprising an array of closely packed components which include fuel elements, the components being arranged with their longitudinal axes generally vertical in groups, at least some of the components in each of several groups are supported in such manner as to tend to tilt the components towards the centre of the respective group whereby the components of each group are urged laterally into abutment with one another, and the fuel elements have interlocking bearing pads intermediate their ends whereby relative lateral movement of two adjacent fuel elements is resisted. By reducing sideways slip of fuel elements the stability of the reactor core is improved during refuelling operations.

The invention also resides in a nuclear reactor fuel element for a nuclear reactor core, in accordance with the preceding paragraph the fuel element comprising a cluster of parallel fuel pins enclosed by a peripheral wrapper of hexagonal cross-section, the bearing pads being in the form of spline-like ribs disposed on each side of the wrapper and extending parallel to the longitudinal axis of the fuel element and interlockable with complementary ribs of pads on adjacent fuel elements in the group.

The invention is applicable to a nuclear reactor core wherein the components, which comprise fuel elements and control rod guide tubes are generally arranged in modules each module comprising a cluster of four components at least three of which are fuel elements, one fuel element being rigidly supported whilst the remaining components are resiliently tilted towards the centre of the cluster to lean on the rigidly supported element.

The invention is also applicable to a nuclear reactor core wherein the fuel elements are arranged in modules, each module comprising a cluster of six fuel elements, each resiliently tilted towards a central void to form a circular arch. The modules may include additional fuel elements disposed outside the clusters and resiliently tilted towards the central voids. The central voids may be used to accommodate a control rod guide tube.

By using a module arrangement of fuel elements wherein one element serves to support the remaining elements and control rod guide tubes of the cluster, or wherein the elements lean on each other in a circular arch, the need for structural members to form leaning posts in the manner described in British Patent No. 1,106,256 is avoided. Such structural members are subject to irradiation embrittlement which could lead to failure within the core.

Constructional embodiments of the invention will now be described, by way of example, with reference to the drawing accompanying the provisional specification wherein:—

Figure 1 is a diagrammatic plan view of a nuclear reactor core,

Figure 2 is a detail of Figure 1 drawn to a large scale,

Figure 3 is a side view of a nuclear reactor fuel element,

Figure 4 is a plan view of part of the fuel element shown in Figure 3 and is a cross-section on line IV—IV of Figure 3,

Figure 5 is a plan view of part of the element shown in Figure 3 and is a cross-section on line V—V of Figure 3,

Figure 6 is fragmentary detail of Figure 3 drawn to a larger scale,

Figure 7 is a diagrammatic plan view of a second construction of nuclear reactor core, and

Figure 8 is a detail of Figure 7 drawn to a larger scale.

In Figure 1 there is shown a fast neutron nuclear reactor comprising a central zone 1 having plutonium enriched fuel elements, an intermediate zone 2 having more highly enriched fuel elements and a zone 3 of breeder fuel elements. In addition to fuel elements the central and intermediate zones include some control rod guide tubes (only two being indicated and designated 'C') and the inner zone also includes some guide tubes for control rods which serve to shut down the reactor (only one being indicated and designated 'S'). Except at the periphery of the breeder zone 3, the components are generally arranged in modules each comprising a cluster of four components of which at least three are fuel elements. One of the fuel elements of each module is rigidly supported in upright position whilst the remaining fuel elements are tilted towards the rigidly supported fuel element. Where one of the components of the module is a control rod guide tube it may be free standing or may lean on the fuel elements but does not have interlocking bearing pads. Figure 2 shows a module of four components comprising types X, Y and Z wherein the component type Z is rigidly supported whilst components type X and Y are tilted towards the centre of the cluster as indicated by arrows designated 4. The rigidly supported components are indicated by cross-hatching in Figure 1 and the four associated components of each module are indicated by broken lines. The arrows 4*a* in Figure 1 indicate the loading direction of the components which are not in regular module. Either of components type 'X' can be a control rod or shut down rod guide tube but neither type 'Y' or type 'Z' can be so used; type Y is excluded because stability of the module depends on the interlocking afforded by this component during refuelling of type 'Z', and type Z is excluded because it defines the position of the modules with respect to the remainder of the core.

The fuel elements, control rod guide tubes and shut down rod guide tubes are generally similar in outward form except that the guide tubes do not have the interlocking bearing pads. A fuel element is shown in Figures 3, 4 and 5. Each fuel element comprises a cluster of fuel pins (not shown) enclosed by a wrapper of hexagonal cross-section and designated 5 in Figure 3. The fuel element has a lower spile 6 which is engageable with a socket associated with a diagrid, for example, as in the manner described in British Patent No. 1,106,256 whereby the fuel elements are disposed generally upright. The elements types X, Y which are arranged to tilt have resilient spikes 6 and the tilt is achieved by eccentricity in the diagrid sockets. The rigidly supported element type Z, of course, has a substantially rigid spike 6. The upper end region of the element has a cylindrical portion 7 and the transition from circular section to hexagonal section is effected by a hexagonal taper 8. The transition from hexagonal section to circular section at the lower end region of the element is effected by a circular taper 9. Immediately above the circular taper there is a group of rib-like, extended corner features or splines 10 projecting outwardly as shown in Figure 4. Intermediate the ends of the element there are bearing pads 11 in the form of spline-like ribs 11*a* on each side of the wrapper 5. Each pad 11 comprises one full width and one half width rib 11*a* which can interlock with a co-operating rib and half width rib 11*a* on an adjacent fuel element as shown in Figure 2. A single bearing pad 11 is shown in Figure 6 the ribs 11*a* having taper lead in surfaces 11*b* and 11*c* at each end.

When a fuel element is being loaded into a reactor core in the presence of installed fuel elements, the fuel element is suspended and lowered to enter the spike 6 alongside the upper cylindrical portion 7 of an installed adjacent element. Further lowering brings the circular taper 9 in contact with a side of the hexagonal taper 8 of an adjacent element so that the fuel element is displaced sideways generally into its correct azimuthal position relative to the centre of the cluster of components. By further lowering of the fuel element the extended corner features 10 abut the sloping hexagonal tapers 8 of the adjacent elements and the reaction between the corner features and the adjacent elements causes rotation of the element to a position such that the bearing pads 11 will pass between adjacent fuel element wrappers 5, and the wrapper 5 of the suspended element will pass between the pads 11 on adjacent elements. When the fuel element is lowered sufficiently to engage the lower ends of the ribs 11*a* with the upper ends of the ribs 11*a* of adjacent elements, the taper lead in surfaces 11*b* of the ribs assist in radial and fine rotational adjustment of the fuel element, and the taper lead in surfaces 11*c* assist in radial alignment, to engage the ribs accurately so that the fuel element can be fully lowered and spiked into the diagrid. The interlocking ribs

11*a* of the bearing pads 11 accurately locate all the components of the cluster and lateral slip of the components is reduced to very small limits.

The second construction of nuclear reactor shown in Figures 7 and 8 is generally similar to the first construction except that fuel elements only are arranged generally in clusters of six, each resiliently tilted towards a central void to form a circular arch. The central void can be occupied by a free standing control rod or shut down rod guide tube. In Figure 7 some of the control rod and shut down rod guides tubes are shown and again designated 'C' and 'S' respectively, but in the breeder zone some of the voids are left vacant some examples being designated '0'. A basic module 12 of six fuel elements is enlarged in some regions, for example, the module designated 13 has an additional fuel element appended to it and the module designated 14 has two additional fuel elements appended to it. The appended fuel elements are arranged to tilt towards the centre of the basic cluster.

WHAT WE CLAIM IS:—

1. A nuclear reactor core comprising an array of closely packed components which include fuel elements, the components being arranged with their longitudinal axes generally vertical in groups, wherein at least some of the components in each of several groups are supported in such manner as to tend to tilt the components towards the centre of the respective group whereby the components of each group are urged laterally into abutment with one another, and wherein the fuel elements have interlocking bearing pads intermediate their ends whereby relative lateral movement of two adjacent fuel elements is resisted.

2. A nuclear reactor core according to claim 1 wherein the components comprise fuel elements and control rod guide tubes and are generally arranged in modules, each module comprising a cluster of four components at least three of which are fuel elements, one fuel element being rigidly supported whilst the remaining components are resiliently tilted towards the centre of the cluster to lean on the rigidly supported element.

3. A nuclear reactor core according to claim 1 wherein the fuel elements are arranged in modules, each module comprising a cluster of six fuel elements, each resiliently tilted towards a central void to form a circular arch.

4. A nuclear reactor core according to claim 3 wherein at least some of the modules have additional fuel elements disposed outside the clusters and resiliently tilted towards the central voids.

5. A nuclear reactor core according to either of claims 3 and 4 wherein the central voids of at least some of the modules acommodate control rod guide tubes.

6. A nuclear reactor fuel element for a nuclear reactor core in accordance with any one of the preceding claims, the fuel element comprising a cluster of parallel fuel pins enclosed by a peripheral wrapper of hexagonal cross-section, the bearing pads being in the form of spline-like ribs disposed on each side of the wrapper and extending parallel to the longitudinal axis of the fuel element and interlockable with complementary ribs of pads on adjacent fuel elements in a group.

7. A nuclear reactor fuel element according to claim 6 wherein the spline like ribs of the bearing pads have taper lead-in surfaces at each end at least on one side and on their faces.

8. A nuclear reactor fuel element according to claim 7 wherein the wrapper of hexagonal cross-section has a correspondingly hexagonal taper in an end region which is uppermost when the element is in a nuclear reactor core and a circular taper at a lower end region of the wrapper, and a group of rib-like, extended corner features disposed above and adjacent the circular taper.

9. A nuclear reactor core substantially as hereinbefore described with reference to Figs 1, 2, 3, 4, 5 and 6 of the drawings accompanying the Provisional Specification.

10. A nuclear reactor core substantially as hereinbefore described with reference to Figs 3, 4, 5, 6, 7 and 8 of the drawing accompanying the Provisional Specification.

11. A nuclear reactor fuel element substantially as hereinbefore described with reference to Figs 3, 4, 5 and 6 of the drawings accompanying the Provisional Specification.

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1444011 PROVISIONAL SPECIFICATION
5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

Fig. 1.

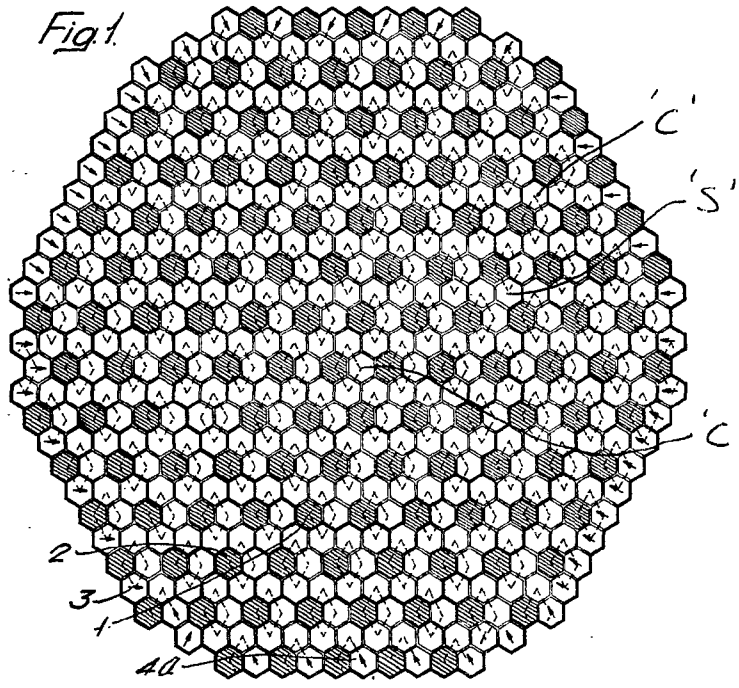
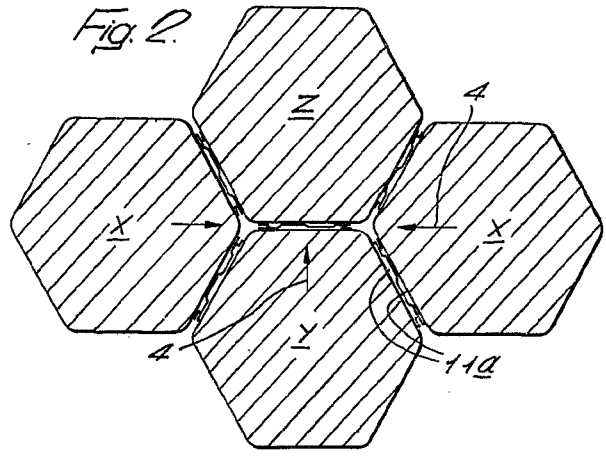


Fig. 2.



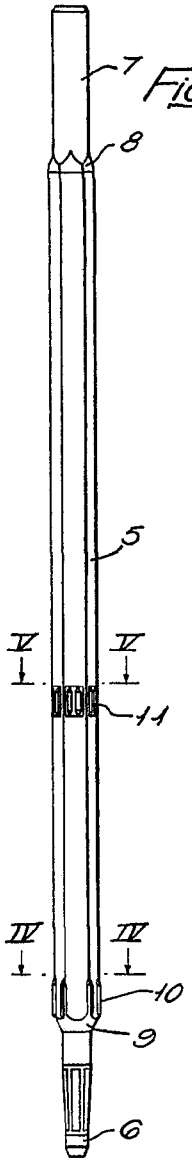


Fig. 3.

Fig. 4.

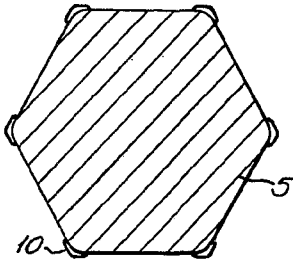


Fig. 5.

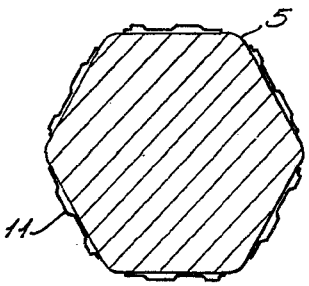


Fig. 6.

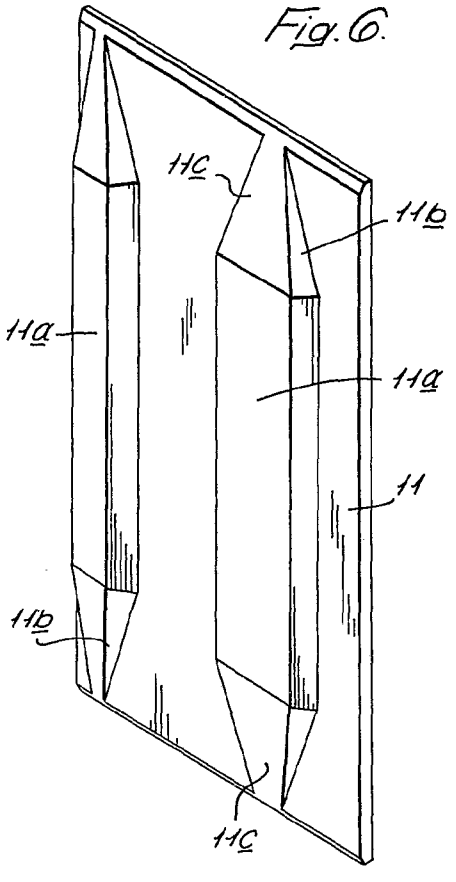


Fig. 7.

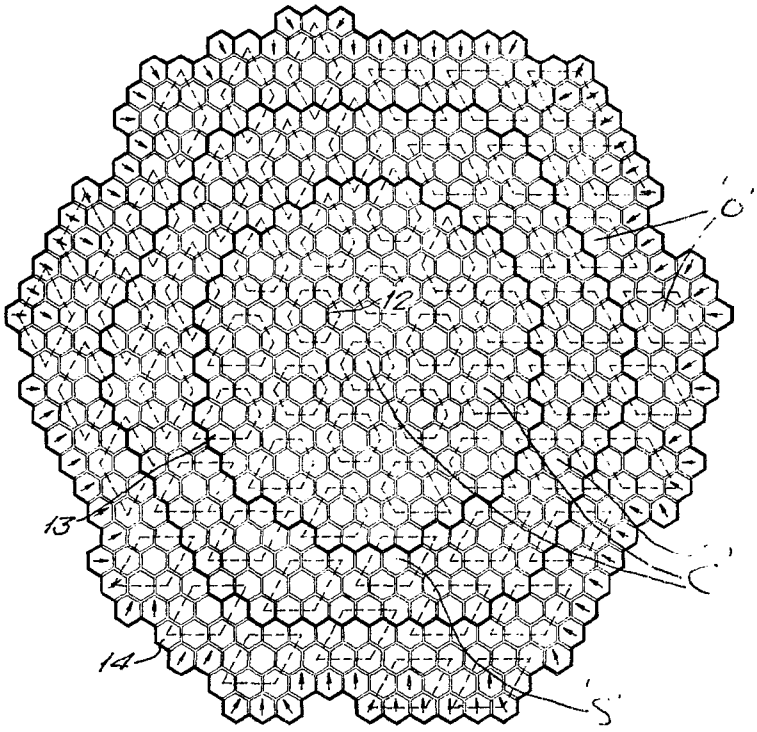


Fig. 8.